TAGUCHI

PHILOSOPHIES & METHODOLOGIES

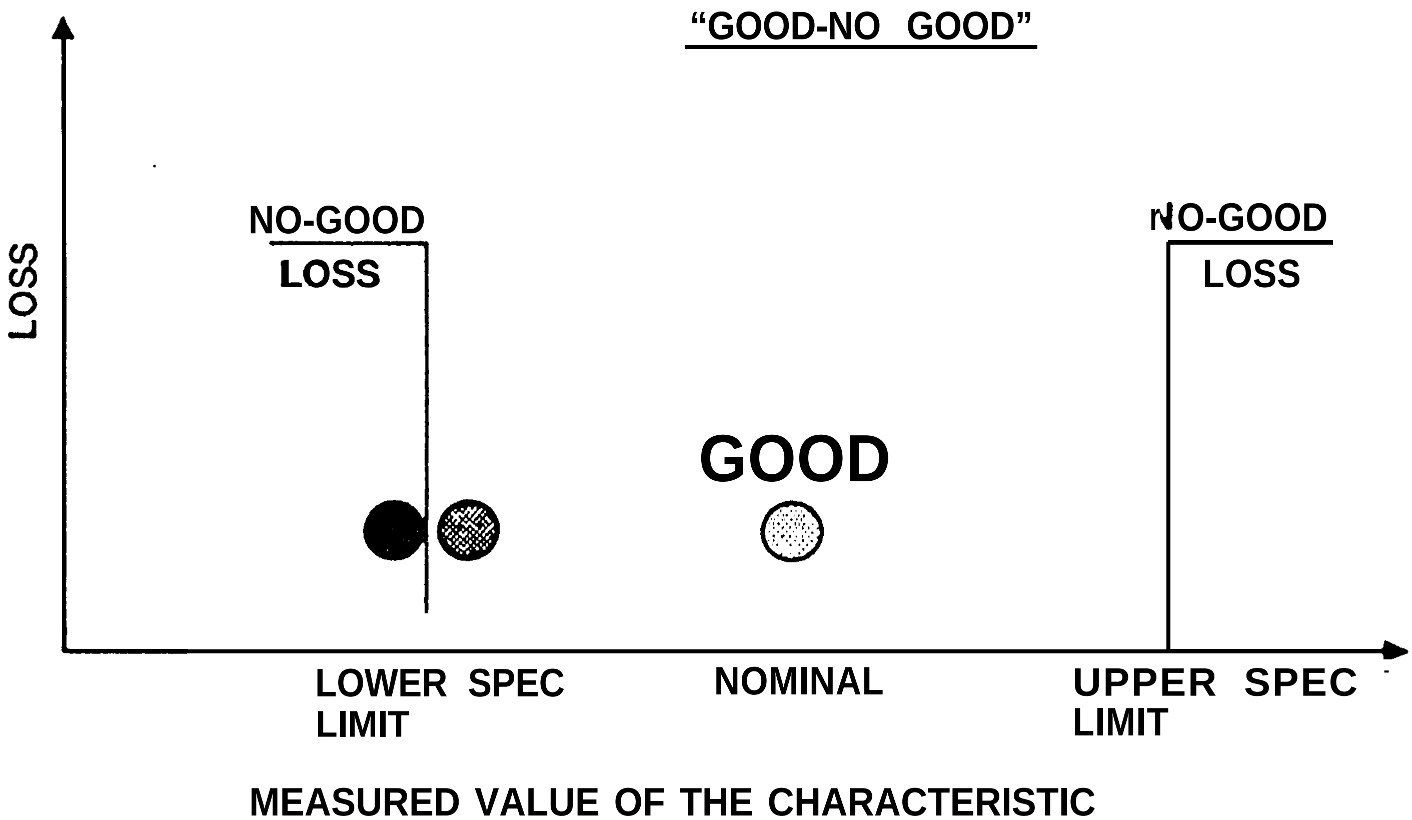
“THE QUALITY OF A PRODUCT IS THE (MINIMUM) LOSS IMPARTED BY THE PRODUCT TO THE SOCIETY FROM THE TIME THE PRODUCT IS SHIPPED”

– DR. G. TAGUCHI

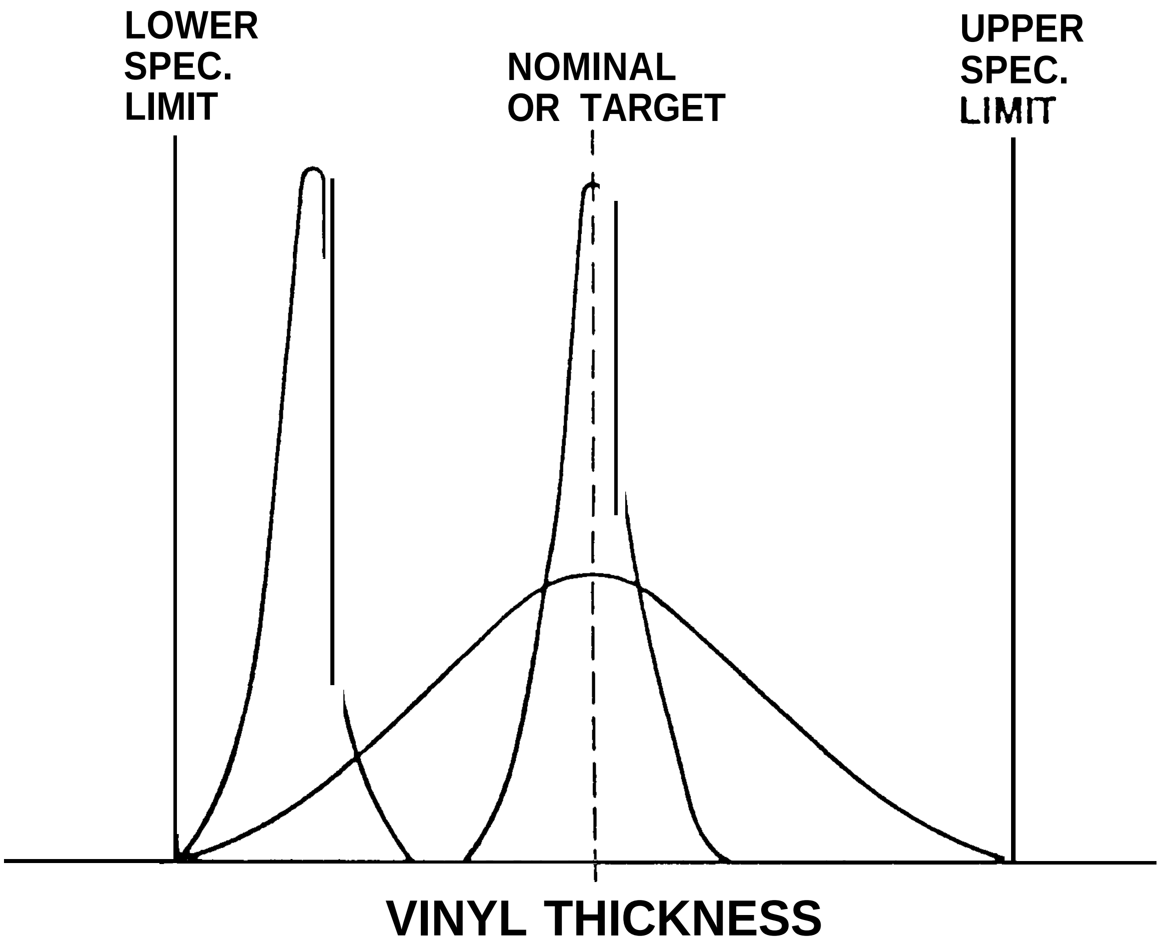
LOSS TO SOCIETY

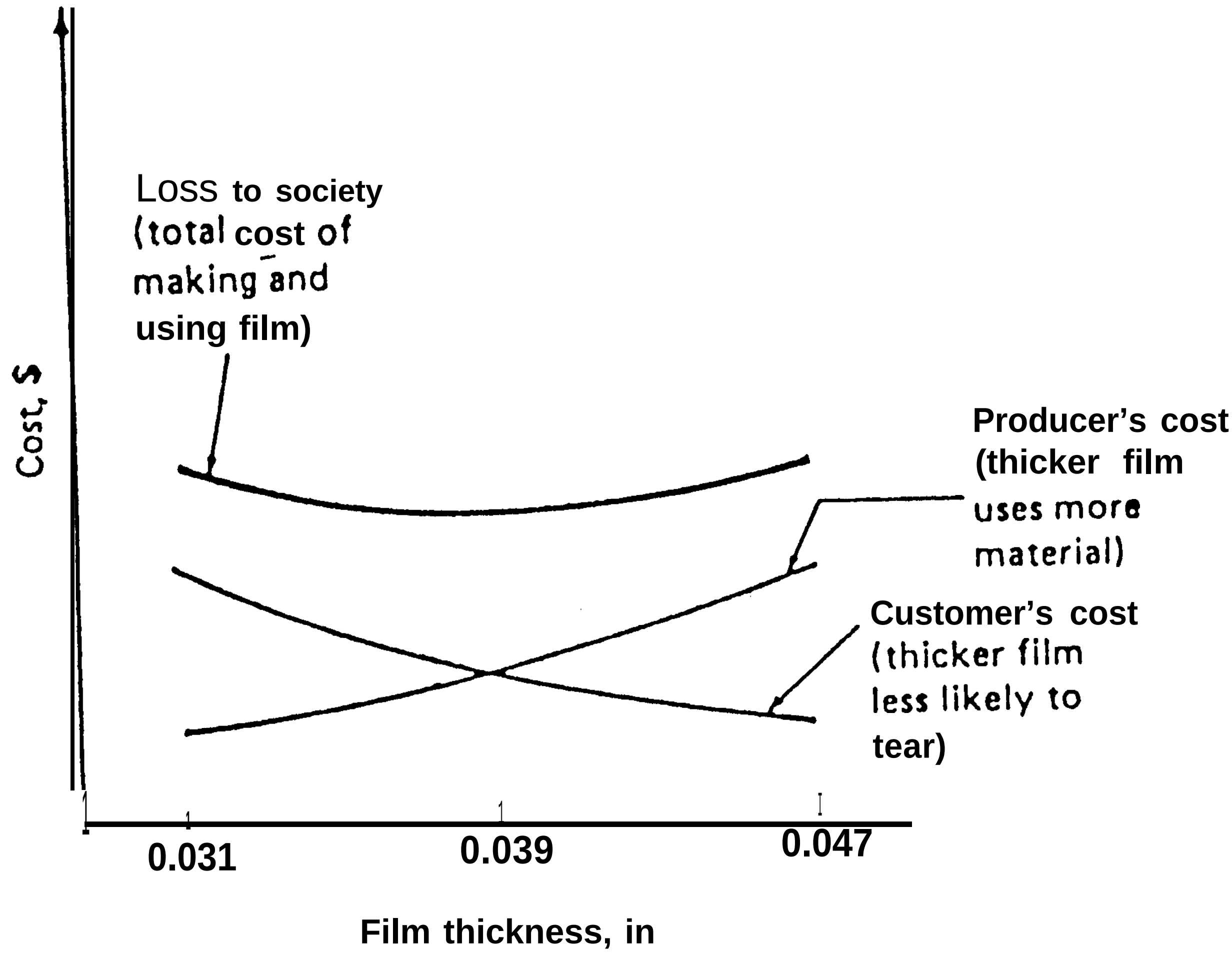
- SCRAP/REWORK
- RETURNS
- WARRANTY C0STS
- CUSTOMER COMPLAINTS
  AND DISSATISFACTION
- TIME AND MONEY
- POTENTIAL LOSS OF MARKET SHARE

MAKE IT TO SPECIFICATIONS



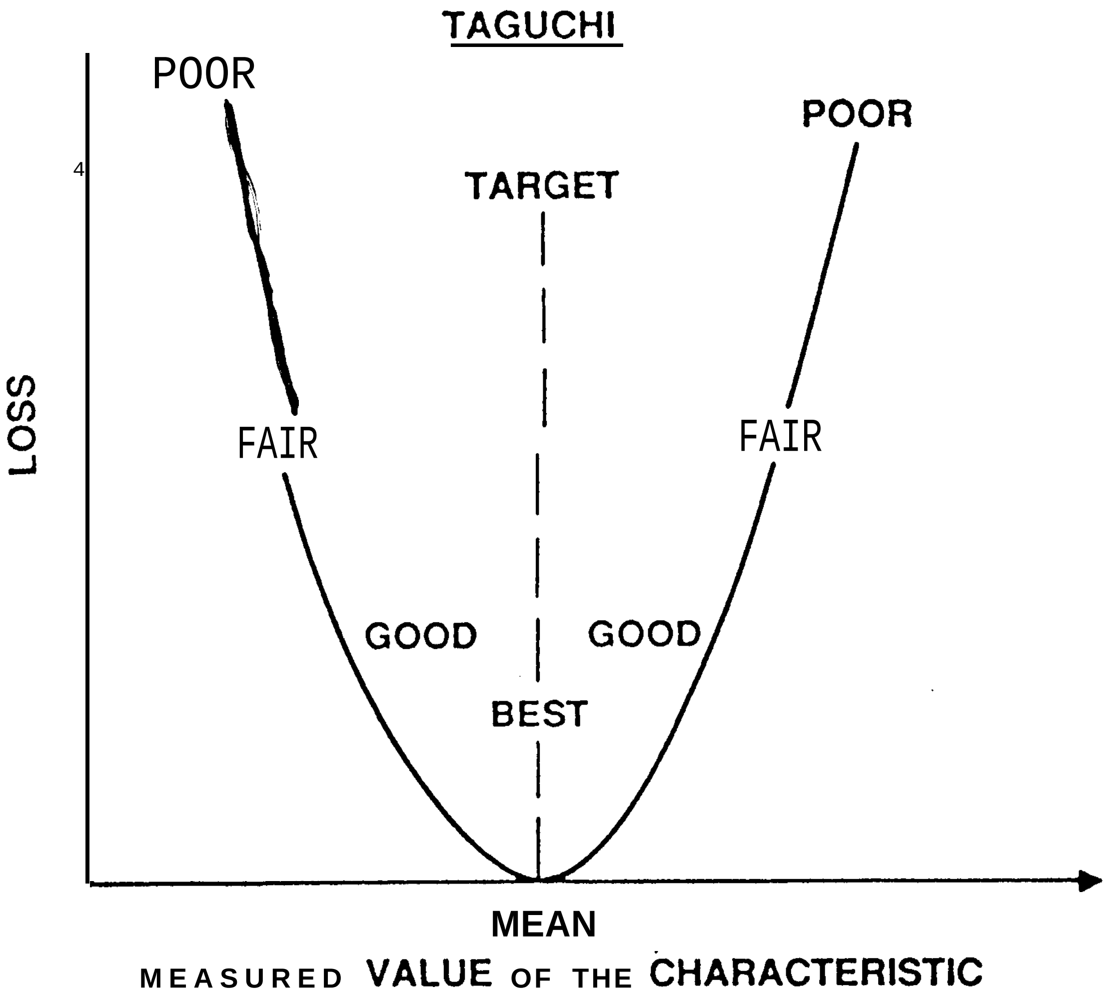
EXAMPLE OF VINYL THICKNESS SPECIFICATION VS. CUSTOMER EXPECTATION





Loss to society
(total cost of
making and
using film)
Producer's cost
(thicker film
uses more
material)
Customer's cost
(thicker film
less likely to
tear)
Cost, $
0.031
0.039
0.047
Film thickness, in

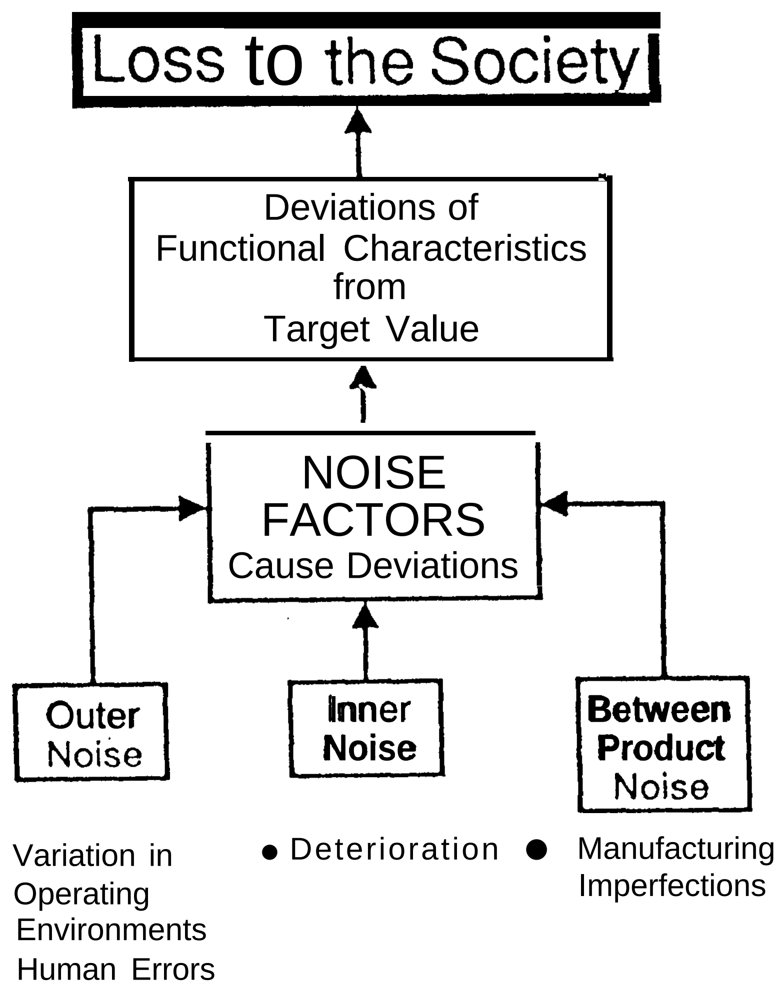
INTERPRETATION OF LOSS



MEASURABLE CHARACTERISTICS OF GOODNESS

- Nominal is best . . . . e.g. Environment
- Smaller the better. . . . e.g. Impurities
- Larger the better . . . . e.g. Miles per gallon

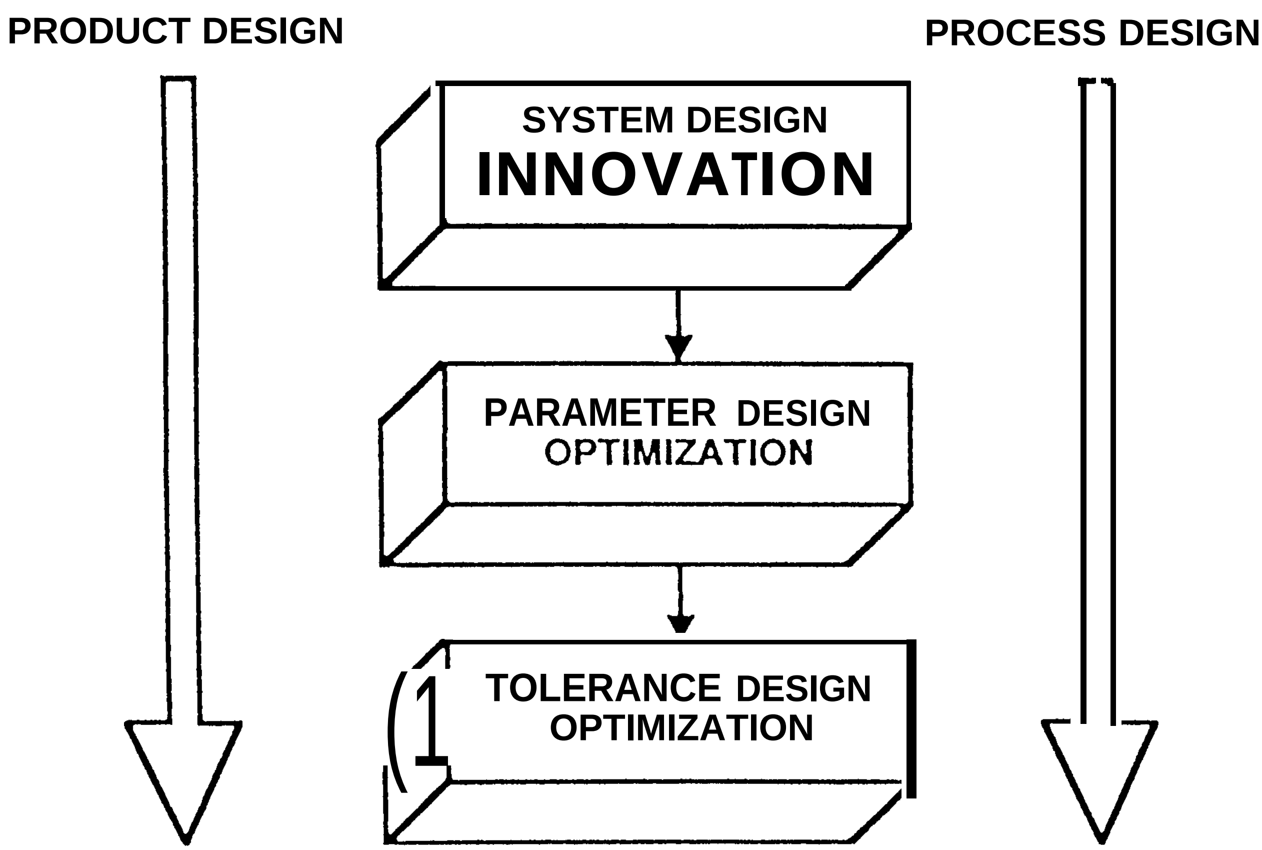
NOISE FACTORS



Examples of Factors

	Product Design	Process Design
o Outer Noise	Consumer's usage conditions Low temperature High temperature Tempera Cure change Shock Vibration Humidity	Ambient temperature Humidity Seasons Incoming material variation Operators Voltage change Batch to batch variation
o Inner Noise	Deterioration of parts Deterioration of material Oxidization (rust)	Machinery aging Tool wear Deterioration
o Between Product	Piece to piece variation where they are supposed to be the same	Process to process variation where they are supposed to be the same
Controllable Factors	All design parameters Such as dimension ● aterial .configuration	All process design parameters All process setting parameters

STAGES IN DESIGN



QUALITY ENGINEERING

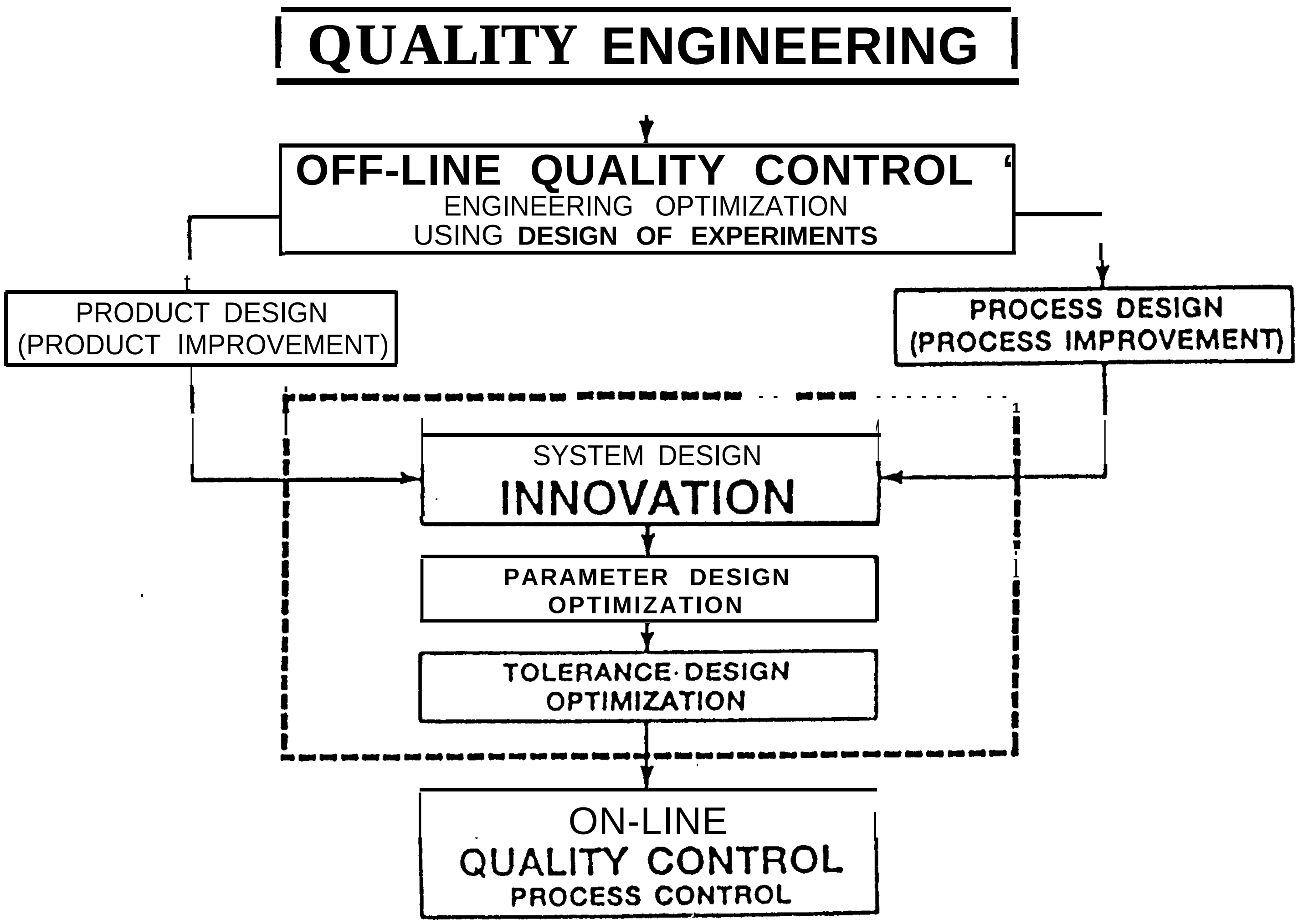
Quality Engineering can be viewed in two distinct phases

Off-Line Quality Control

On-Line Quality Control

Off-Line Quality Control activities occur at the product ● nd process design stages. hey optimize product and process design using design of experiments. The design process includes system design, parameter design and tolerance design.

On-Line Quality Control activities occur at the actual production stage. They include process control systems, use of adjustment factors ● nd inspection. SPC is one way to do On-Line Quality Control.


QUALITY ENGINEERING
OFF-LINE QUALITY CONTROL
ENGINEERING OPTIMIZATION
USING DESIGN OF EXPERIMENTS
PRODUCT DESIGN
(PRODUCT IMPROVEMENT)
PROCESS DESIGN
(PROCESS IMPROVEMENT)
SYSTEM DESIGN
INNOVATION
PARAMETER DESIGN
OPTIMIZATION
TOLERANCE DESIGN
OPTIMIZATION
ON-LINE
QUALITY CONTROL
PROCESS CONTROL

TYPESOF QUALITY CHARACTERISTICS

- Measurable characteristics are amenable to measurement on a continuous scale.

- Attribute characteristics are not continuously scalable but can be classified on a discretely graded scale. They are often based. on subjective judgments such as good, better, best.

- Dynamic characteristics are functional quality characteristics of a "system" determined on the basis of Input to the system and resulting output. An automobile powertrain is a good example of this type of characteristic. As engine speed changes (input) the transmission reacts and down-shifts, up-shifts or remains in the same gear.

Measurable characteristics can be classified into three types:

- **Nominal the Best** A characteristic with a specific target value.
- **Smaller the Better** Here the ultimate target is zero.
- **Larger the Better** The target is infinity.

For each of these types it is possible to develop a function to quantify the loss incurred by failure to achieve the desired quality.

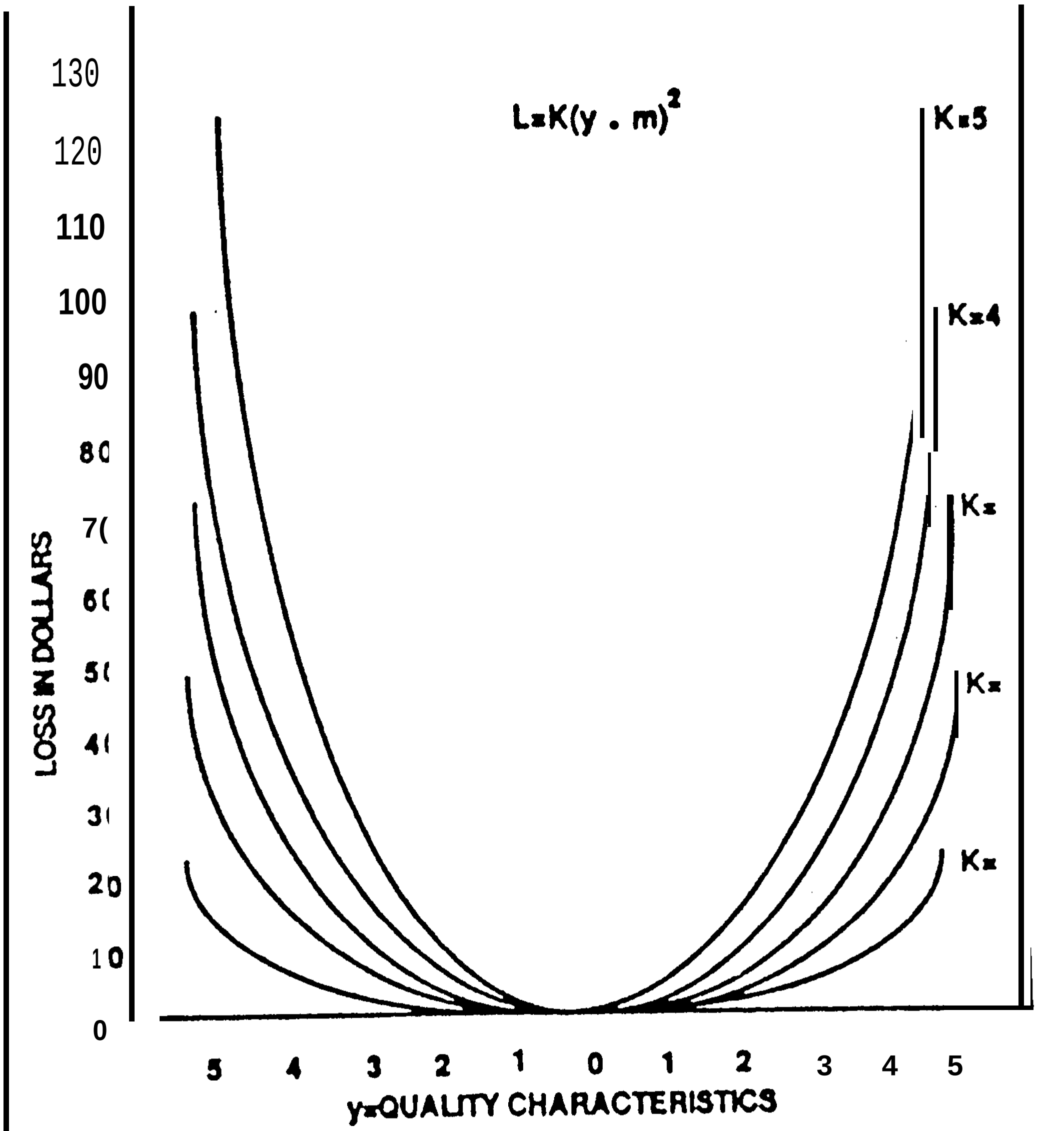
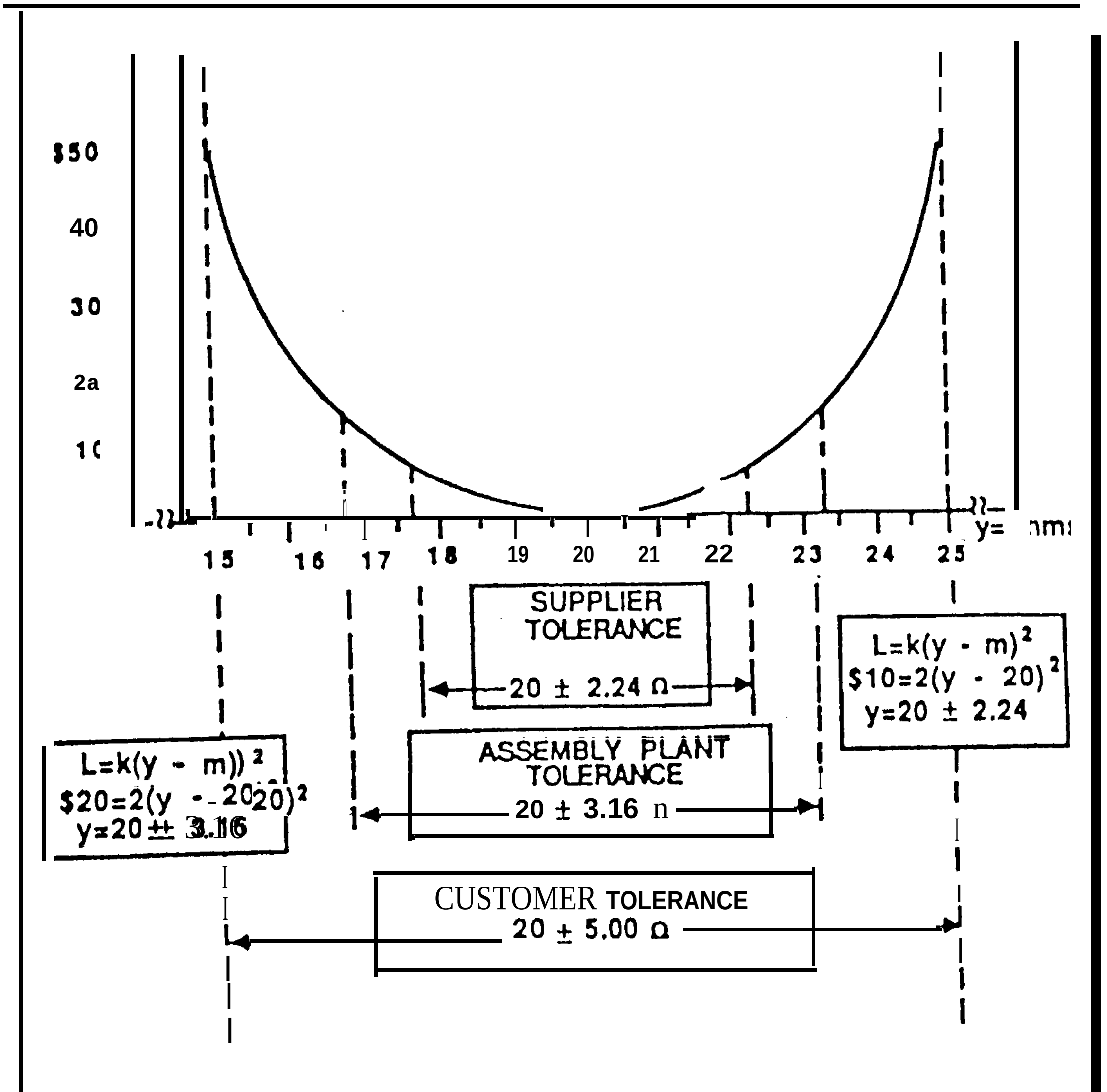


FIGURE 2.4 QUALITY LOSS AS A FUNCTION OF K



QUALITY LOSS FUNCTION

TAGUCHI'S QUALITY ENGINEERING

OFF-LINE

APPLIED FOR	• PRODUCT OPTIMIZATION
	• PROCESS OPTIMIZATION
USING	• ORTHOGONAL ARRAYS
	• SIGNAL-TO-NOISE RATIOS
	• QUALITY LOSS FUNCTION
EMPHASIZING	• EFFICIENT EXPERIMENTATION AND/OR SIMULATION
	• REDUCING VARIABILITY
	• LOW COST
	• ROBUSTNESS OF PRODUCTS

ON-LINE

APPLIED	• MANUFACTURING STAGE
USING	• LOSS FUNCTION
DETERMINING	• CHECKING INTERVAL
	• ADJUSTMENT LIMIT
	• INSPECTION NEEDS
PREVENTING	• SYSTEM DOWNTIME
TO	• REDUCE THE VARIABILITY OF A PROCESS
	• REDUCE THE QUALITY LOSS OF A PROCESS

Parameter Design

- Determination of parameter values least sensitive to noise
- Involves use of orthogonal arrays and signal-to-noise ratic
- Minimal cost

STEPS IN DESIGNING EXPERIMENTS

1. Define the problem
2. Determine the objective
3. Brainstorm
4. Design the experiment
5. Conduct the experiment

   and collect data
6. Analyze the data

   by: Regular analysis
   S/N analysis
7. Interpret results
8. Always-Always-Always CONFIRM

THE ROLE OF AN ORTHOGONAL ARRAY

The goal of quality engineering is to ensure that we can maximize product and process performance and minimize sensitivity to noise, at minimum cost. The role of an orthogonal array is to let us evaluate a design with respect to robustness and cost.

We will see that in quality engineering an orthogonal array is an InspectIon device for preventing a 'poor' design from going downstream. It is a tool for minimizing on-line inspection.

ORTHOGONAL ARRAY L_8 (2^7)

EXAMPLE - 8 TESTS OF 7 PARAMETERS

Number	A 1	B 2	c 3	D 4	E 5	F 6	G 7	Results
1	1	1	1	1	1	1	1	Y,
2	1	1	1	2	2	2	2	y_2
3	1	2	2	1	1	2	2	Y3
4	1	2	2	2	2	1	1	Y4
5	2	1	2	1	2	1	2	Y5
6	2	1	2	2	1	2	1	y_6
7	2	2	1	1	2	2	1	Y7
8	2	2	1	2	1	1	2	y_8

Orthogonality of Columns A and B

For Al, Number of B,: Number of B_2 = 2:2 = 1:1

For A_2, Number of B,: Number of B_2 = 2:2 = 1:1

ONE-FACTOR-AT-A-TIME-EXPERIMENT

EXPERIMENT NUMBER	A	B	c	D	E	F	G	EXPERIMENTAL RESULTS
1	A_1	B_1	C_1	D_1	E_1	F_1	G_1	Result 1
2	A_2	B_1	C_1	D_1	E_1	F_1	G_1	Result 2
3	A_2	B_2	C_1	D_1	E_1	F_1	G_1	Result 3
4	A_2	B_2	C_2	D_1	E_1	F_1	G_1	Result 4
5	A_2	B_2	C_2	D_2	E_1	F_1	G_1	Result 5
6	A_2	B_2	C_2	D_2	E_2	F_1	G_1	Result 6
7	A_2	B_2	C_2	D_2	E_2	F_2	G_1	Result 7
8	A_2	B_2	C_2	D_2	E_2	F_2	G_2	Result 8

Corn

Al

Al and A_2 are compared under fixed conditions

for the same B, C,D...

FULL FACTORIAL EXPERIMENT

	A	B	C	D	E	F	G	DATA
1	1	1	1	1	1	1	1	
2	1	1	1	1	1	1	2	
3	1	1	1	1	1	2	1	
4	1	1	1	1	1	2	2	
5	1	1	1	1	2	1	1	
6	1	1	1	1	2	1	2	
7	1	1	1	1	2	2	1	
8	1	1	1	1	2	2	2	
9	1	1	1	2	1	1	1	
10	1	1	1	2	1	1	2	
11	1	1	1	2	1	2	1	
12	1	1	1	2	1	2	2	
13	1	1	1	2	2	1	1	
14	1	1	1	2	2	1	2	
15	1	1	1	2	2	2	1	
16	1	1	1	2	2	2	2	
17	1	1	2	1	1	1	1	
18	1	1	2	1	1	1	2	
19	1	1	2	1	1	2	1	
20	1	1	2	1	1	2	2	
21	1	1	2	1	2	1	1	
22	1	1	2	1	2	1	2	
	●	●	●	●	●	●	●	
	●	●	●	●	●	●	●	
	●	●	0	●	●	●	●	
126	2	2	2	2	2	1	2	
127	2	2	2	2	2	2	1	
128	2	2	2	2	2	2	2	

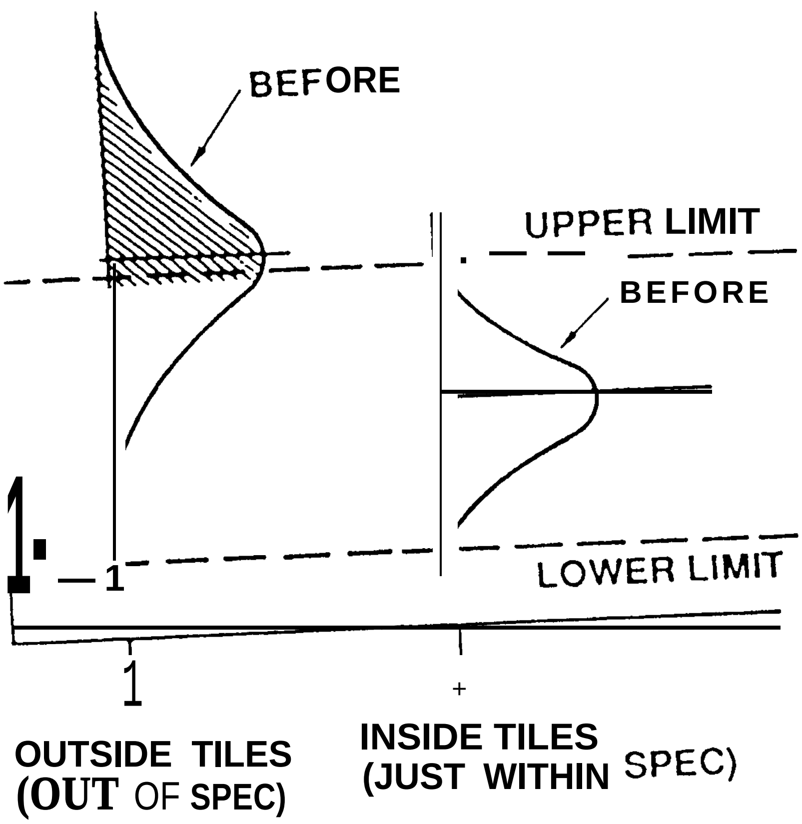
FULL FACTORIAL 2^7
128 EXPERIMENTAL **RUNS**

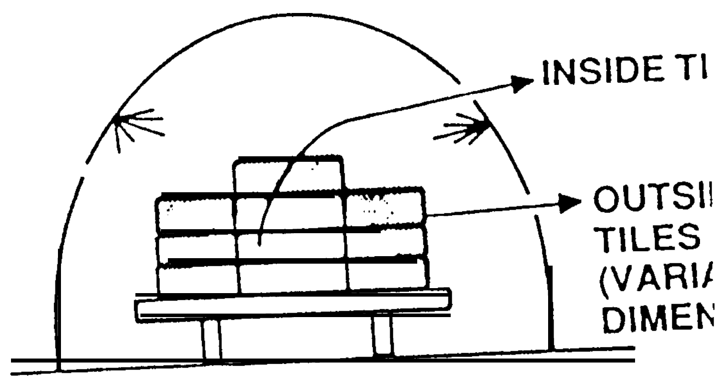
TILE MANUFACTURING

EXPERIMENT

TILE MANUFACTURING PROCESS

BEFORE THE EXPERIMENT





EXPERIMENT ON TILE MANUFACTURING

Raw material Crushing & mixing - Molding → Calcining → Glazing → Calcining

Control **Factors and Levels**

- **A: Amount of Limestone** — **A_1 = 5% (new), A_2 = 1°/0 (existing)**
- **B: Fineness of the additive,** — **B, = Coarser (existing), B_2 = Finer. (new)**
- **C: Amount of agalmatolite,** — **c, = 43'% (new), C_2 = 53% (existing)**
- **D: Type of agalmatolite,** — **D, = Existing combination**
  D_2 = New combination
- **E: Raw material charging quantity** — **El = 1300 Kg (new), E_2 = 1200 Kg (existing)**
- **F: Amount of waste return** — **F, = 0°/0 (new), F_2 = 4% (existing)**
- **G: Amount of feldspar** — **G_1 = 0% (new), G_2 = 5% (existing)**

ORTHOGONAL ARRAY $L_8(2^7)$

7 FACTORS 2 LEVELS EACH 8 EXPERIMENTAL RUNS

Number	A 1	B 2	C 3	D 4	E 5	F 6	G 7	Results
1	1	1	1	1	1	1	1	Y,
2	1	1	1	2	2	2	2	y_2
3	1	2	2	1	1	2	2	Y3
4	1	2	2	2	2	1	1	Y4
5	2	1	2	1	2	1	2	y_5
6	2	1	2	2	1	2	1	y_6
7	2	2	1	1	2	2	1	Y7
8	2	2	1	2	1	1	2	y_8

TEST DATA

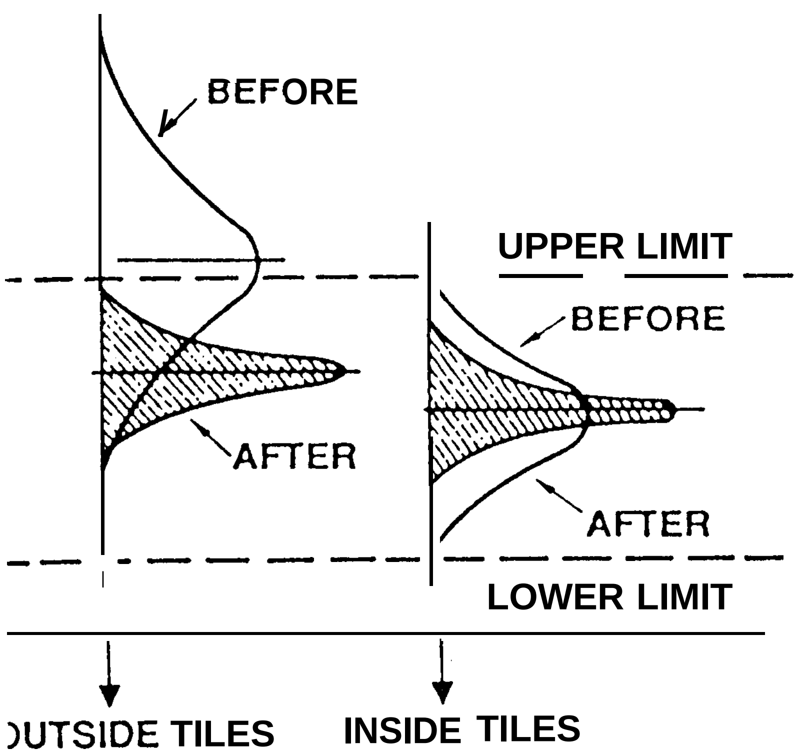
		A	B	C	D	E	F	G	
	L8 ABC DEFG	CONTNT OF LIME	FINE-NESS	AGAL-TOLITE	KIND OF AGALMA	CHG QTY	WASTE RETURN	FLD SPAR	NO. OF DEFECT.
No.	1 2 3 4 5 6 7	1	2	3	4	5	6	7	per 100
1	1 1 1 1 1 1 1	5	CRSE	43	EXSTG	1300	0	0	16
2	1 1 1 2 . 2 2 2	5	CRSE	43	NEW	1200	4	5	17
3	1 2 2 1 1 2 2	5	FINE	53	EXSTG	1300	4	5	12
4	1 2 2 2 2 1 1	5	FINE	53	NEW	1200	0	0	6
5	2 1 2 1 2 1 2	1	CRSE	53	EXSTG	1200	0	5	6
6	2 1 2 2 1 2 1	1	CRSE	53	NEW	1300	4	0	88
7	2 2 1 1 2 2 1	1	FINE	43	EXSTG	1200	4	0	42
8	2 2 1 2 1 1 2	1	FINE	43	NEW	1300	0	5	26

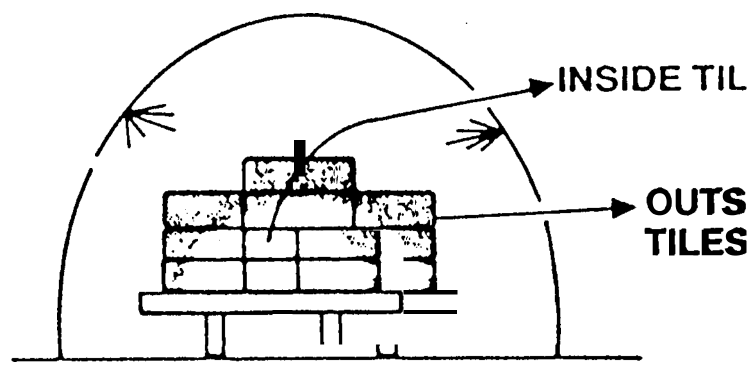
ANALYSIS OF RESULTS

	TOTAL DEFECTS	% DEFECTIVE		TOTAL DEFECTS	% DEFECTIVE
AI A2	51 142	12.75 35.50	E1 E2	122 71	30.50 17.75
B1 62	107 86	26.75 21.50	F1 F2	54 139	13.50 34.75
c I C2	101 92	25.25 23.00	G1 G2	132 61	33.00 15.25
D1 D2	76 117	19.00 29.25	TOTAL	193	24.12

PAPER CHAMPION AI B2 C2 D1 E2 F1 G2
WINNING COMBINATION A1 B2 CI D1 E2 F1 G2

TILE MANUFACTURING PROCESS CONFORMATION





QUALITY LOSS FUNCTION

$$L(y) = k(y-m)^2$$

$L(y)$ = loss in dollars per unit product when the quality characte is equal to y.

y = the value of the quality characteristic (i.e., length, width, concentration, surface finish, flatness, etc.)

m = target value of y

k = a proportionality constant. As will be seen later, k depends on the financial importance of the quality characteristic. If y is, for example, a critical dimension of a safety device on a nuclear reactor, then k becomes a very high figure.